# CERTIFICATE

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[Title of the Invention] METHOD FOR CONTROLLING FREQUENCY OF SURFACE ACOUSTIC WAVE DEVICE AND ELECTRONIC APPARATUS

[Claims]

[Claim 1] A method for controlling the frequency of a surface acoustic wave device comprising a quartz substrate; and IDT electrodes formed on the quartz substrate for exciting pseudo-longitudinal leaky surface acoustic waves,

wherein the frequency is controlled by controlling the thickness of the quartz substrate using the surface that faces the surface where the IDT electrodes are formed.

[Claim 2] The method for controlling the frequency of the surface acoustic wave device according to Claim 1, wherein the frequency is controlled by dry etching the surface that faces the surface of the quartz substrate where the IDT electrodes are formed.

[Claim 3] The method for controlling the frequency of the surface acoustic wave device according to Claim 1 or 2, wherein at least one of the surface of the quartz substrate where the IDT electrodes are formed and the surface of the IDT electrodes is etched, thereby controlling the frequency before controlling the frequency.

[Claim 4] A method for controlling the frequency of a surface acoustic wave device comprising a quartz substrate; and IDT electrodes formed on the quartz substrate for exciting pseudo-longitudinal leaky surface acoustic waves,

wherein the frequency is controlled by arranging the surface

acoustic wave device such that the quartz substrate is held in a package so that the IDT electrodes face downward in a chamber, to which an etching gas is introduced, and etching the surface that faces the surface of the quartz substrate where the IDT electrodes are formed until a desired frequency is obtained while measuring the input-output characteristic of the surface acoustic wave device.

[Claim 5] A method for controlling the frequency of a surface acoustic wave device comprising a quartz substrate; and IDT electrodes formed on the quartz substrate for exciting pseudo-longitudinal leaky surface acoustic waves,

wherein the frequency is controlled by arranging the surface acoustic wave device such that the quartz substrate is held in a package with an aperture so that the IDT electrodes face upward in a chamber, to which an etching gas is introduced, and etching the surface that faces the surface of the quartz substrate where the IDT electrodes are formed until a desired frequency is obtained while measuring the input-output characteristic of the surface acoustic wave device.

[Claim 6] An electronic apparatus comprising a surface acoustic wave device as a filter or a resonator,

wherein the surface acoustic wave device is a surface acoustic wave device whose frequency is controlled by the frequency controlling method according to any one of Claims 1 to 5.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a method for controlling the frequency of a surface acoustic wave device and an electronic apparatus using a surface acoustic wave device controlled by the frequency controlling method.

[0002]

[Description of the Related Art]

A surface acoustic wave device is a circuit element for converting electric signals into surface waves, thereby processing signals. The surface acoustic wave device is widely used as a filter and a resonator. In common, the surface acoustic wave device is obtained by disposing an electrode formed of a conductive film, which is referred to as IDT electrode, on a piezoelectric acoustic substrate (a piezoelectric substrate) and performs conversion and inversion from the electric signals to the surface waves.

[0003]

The characteristic of the surface acoustic wave device depends on the transfer characteristic of the surface acoustic wave for transferring the piezoelectric substrate. In particular, in order to correspond to increase in the frequency of the surface acoustic wave device, it is necessary to use a surface acoustic wave having high phase velocity.

When a pseudo-longitudinal leaky surface acoustic wave having the high phase velocity is used by using crystal, the width of an electrode line for processing a signal having a frequency of 1 [GHz] is 1.4 [μm]. Therefore, it is possible to manufacture a surface acoustic wave device

capable of making electrodes minute and of processing signals having frequencies of 1 to 3 [MHz] by a current electrode processing technology.

[0004]

However, the electrodes are made finely according to the surface acoustic wave device operating at a high frequency. Therefore, the completed sizes such as the widths and the thickness of the electrodes are not uniform. As a result, a center frequency changes, thereby deteriorating a yield rate.

The frequency of the surface acoustic wave device is controlled by finely etching the electrode of a chip or the surface of the piezoelectric substrate. Among frequency controlling devices, a reactive ion etching (RIE) device is most precise. Also, unevenness of qualities of manufactured products is small.

[0005]

The frequency of the surface acoustic wave device is controlled by etching electrode materials such as aluminum using the RIE device and a chlorine-based gas, thereby increasing the frequency. In the frequency controlling method, the oxide film naturally formed on the surface of the electrode as well as the electrode is etched. Therefore, oxidation proceeds again after controlling the frequency. As a result, changes in the thickness of the oxide film affect the center frequency of a device.

[0006]

Since the oxidation gradually proceeds, the center frequency must be measured in a state where the oxide film is stabilized. When the

center frequency is measured in a state where the oxide film is unstable, the measured center frequency changes when products are forwarded due to oxidation after an assembling process.

Since the oxide film on the surface of the electrode is naturally formed, unless the thickness of the oxide film is controlled or managed, the center frequency changes with the lapse of time and the reliability of a device is significantly affected. In particular, since the width of an electrode or the thickness of an electrode film is reduced in the surface acoustic wave device having a high frequency (surface acoustic device), a method for controlling the frequency more correctly is desired.

[0007]

As a method for correctly controlling the frequency, a method has been known in which the frequency is controlled by intentionally forming the oxide film of the electrode to a thickness where a chemical combination with oxygen in the air does not occur (For example, see Patent Document 1.). However, according to the method, an oxide film forming process and an electrode etching process are repeatedly performed. Therefore, a gas inside an REI etching manufacturing chamber must be exchanged, thereby making processes complicated.

[0008]

On the other hand, it is possible to relatively increase the thickness of the electrode and to reduce the center frequency by exchanging a reaction gas from a chlorine-based gas to a fluorine-based gas, thereby etching the surface of a quartz substrate. When the

surface of the quartz substrate is etched by the fluorine-based gas, the thickness of the electrode oxide film does not change. Therefore, it is not necessary to consider the influence of the thickness of the oxide film. As a result, it is necessary to etch the surface of the quartz substrate only to a thickness where a desired frequency is obtained.

[0009]

According to this method, the surface of the electrode film deteriorates and aluminum fluoride is formed because highly reactive fluorine based radical chemically combines with aluminum that is a material of the electrode film on the surface of the surface acoustic wave device. When the chip is left in the air, the frequency changes and so-called plus shift is caused.

[0010]

In order to solve the problems, a method has been known in which the oxide film is formed on the surface of the IDT electrode before controlling the frequency by the fluorine-based gas, thereby protecting the surface of the IDT electrode by the firm oxide film (For example, see Patent Document 2). As a result, the IDT electrode is not eroded by reactive fluorine such as the fluorine-based radical though plasma etching is performed using the fluorine-based gas.

[0011]

However, in a process of forming an electrode by dry etching, aluminum etched by plasma resides on the surface of the substrate. The residing aluminum may change the transfer characteristic during a process of controlling the frequency and undesirably change the

frequency.

[0012]

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 2000-156620

[Patent Document 2] Japanese Unexamined Patent Application Publication No. 2002-33633

[0013]

[Problems to be Solved by the Invention]

As mentioned above, several methods are used for controlling the frequency of the surface acoustic wave device. However, as the operation frequency of the surface acoustic wave device increases, the IDT electrode formed on the quartz substrate becomes fine. The amount of changes in the center frequency increases because completed sizes such as the widths of the electrodes and the thickness of the films are not uniform.

[0014]

For this reason, it is required to precisely control the frequency in the method for controlling the frequency of the surface acoustic wave device. At the same time, it is preferable to realize the surface acoustic wave device capable of reducing changes in the center frequency with the lapse of time after controlling the frequency and of performing stable operations for a long time.

Accordingly, an object of the present invention is to provide a method for controlling the frequency of a surface acoustic wave device capable of realizing a surface acoustic wave device capable of precisely

controlling the frequency, of reducing changes in the center frequency with the lapse of time after controlling the frequency, and of performing a stable operation for a long time.

[0015]

In addition, another object of the present invention is to provide an electronic apparatus using a filter or a vibrator capable of reducing changes in the center frequency with the lapse of time and of performing a stable operation for a long time.

[0016]

[Means for Solving the Problems]

In order to solve the above problems and to achieve the above objects, the respective inventions are formed as follows.

That is, according to a first invention, there is provided a method for controlling the frequency of a surface acoustic wave device comprising a quartz substrate; and IDT electrodes formed on the quartz substrate for exciting pseudo-longitudinal leaky surface acoustic waves, wherein the frequency is controlled by controlling the thickness of the quartz substrate using the surface that faces the surface where the IDT electrodes are formed.

[0017]

According to a second invention, in the method for controlling the frequency of the surface acoustic wave device of the first invention, the frequency is controlled by dry etching the surface that faces the surface of the quartz substrate where the IDT electrodes are formed.

According to the first and second inventions, it is possible to

control the frequency without eroding the electrode patterns formed on the electrode-formed surface of the quartz substrate. Therefore, it is possible to realize the surface acoustic wave device capable of reducing changes in the center frequency with the lapse of time and of performing a stable operation for a long time.

[0018]

In addition, it is possible to precisely control the frequency because changes in the frequency with respect to the etching amount are small compared with the case where the frequency is controlled by etching the electrode-formed surface.

According to a third invention, in the method of controlling the frequency of the surface acoustic wave device according to the first or second invention, at least one of the surface of the quartz substrate where the IDT electrodes are formed and the surface of the IDT electrodes is etched, thereby controlling the frequency before controlling the frequency.

[0019]

With this, when it is necessary to significantly control the frequency, it is possible to precisely control the frequency by etching the surface that faces the electrode-formed surface after roughly controlling the frequency by wet etching the electrode-formed surface. Therefore, it is possible to control the frequency for a short time.

In this case, it is not necessary to etch the electrode-formed surface using the plasma. Therefore, it is possible to provide a surface acoustic wave device capable of preventing the frequency from

changing due to the residing aluminum like in the conventional art and of performing a stable operation for a long time.

[0020]

According to a fourth invention, there is provided a method for controlling the frequency of a surface acoustic wave device comprising a quartz substrate; and IDT electrodes formed on the quartz substrate for exciting pseudo-longitudinal leaky surface acoustic waves, wherein the frequency is controlled by arranging the surface acoustic wave device such that the quartz substrate is held in a package so that the IDT electrodes face downward in a chamber, to which an etching gas is introduced, and etching the surface that faces the surface of the quartz substrate where the IDT electrodes are formed until a desired frequency is obtained while measuring the input-output characteristic of the surface acoustic wave device.

[0021]

With this, it is possible to etch the surface that faces the electrode-formed surface of the quartz substrate after mounting the quartz substrate where the IDT electrodes are formed on the package and to easily control the frequency of the surface acoustic wave device.

According to a fifth invention, there is provide a method for controlling the frequency of a surface acoustic wave device comprising a quartz substrate; and IDT electrodes formed on the quartz substrate for exciting pseudo-longitudinal leaky surface acoustic waves, wherein the frequency is controlled by arranging the surface acoustic wave device such that the quartz substrate is held in a package with an aperture so

that the IDT electrodes face upward in a chamber, to which an etching gas is introduced, and etching the surface that faces the surface of the quartz substrate where the IDT electrodes are formed until a desired frequency is obtained while measuring the input-output characteristic of the surface acoustic wave device.

[0022]

With this, it is possible to easily control the frequency of the surface acoustic wave device by etching the surface that faces the electrode-formed surface of the quartz substrate even when the surface acoustic wave element is mounted on the package so that the IDT electrodes face upward and the wire bonding is performed.

According to a sixth invention, there is provided an electronic apparatus comprising a surface acoustic wave device as a filter or a resonator, wherein the surface acoustic wave device is a surface acoustic wave device whose frequency is controlled by the frequency controlling method according to any one of the first to fifth inventions.

[0023]

With this, it is possible to provide an electronic apparatus using a filter or a vibrator capable of reducing changes in the center frequency with the lapse of time and of performing a stable operation for a long time.

[0024]

[Description of the Embodiments]

Hereinafter, embodiments of the present invention will be described

with reference to the drawings.

Fig. 1(a) is a perspective view illustrating a schematic structure of a surface acoustic wave device a, to which a frequency controlling method according to the present invention is applied. Fig. 1(b) is a cross-sectional view taken along the line A-A of Fig. 1(a).

As shown in Fig. 1, the surface acoustic wave device a includes a quartz substrate 1, an IDT electrode 2 formed on the principal plane of the quartz substrate 1, and reflector electrodes 3a and 3b.

[0025]

In Fig. 1, t denotes the thickness of the quartz substrate 1, P denotes the pitch of the IDT electrode 2, $\lambda$ denotes an IDT wavelength, and h denotes the thickness of the IDT electrode 2. Herein, the quartz substrate 1 is cut so that pseudo-longitudinal leaky surface acoustic waves are excited.

The quartz substrate 1 has a predetermined thickness t and transfers the pseudo-longitudinal leaky surface acoustic waves.

[0026]

The IDT electrode 2 is made of aluminum and is formed on the quartz substrate 1. The IDT electrode 2 excites the pseudo-longitudinal leaky surface acoustic wave by supplying a driving voltage and outputs the vibration of a predetermined frequency.

The reflector electrodes 3a and 3b are made of aluminum and are formed on the quartz substrate 1 so as to interpose the IDT electrode 2. The reflector electrodes 3a and 3b reflect and hold the pseudo-longitudinal leaky surface acoustic wave excited by the IDT electrode 2.

[0027]

In the surface acoustic wave device a having the above structure, when it is necessary to control the frequency as mentioned hereinafter, at least the surface 1b that faces the electrode formed surface of the quartz substrate 1 is etched, thereby controlling the thickness t of the quartz substrate 1 so that the desired center frequency is obtained.

Fig. 2 is a cross-sectional view of the main portion of a surface acoustic wave device b, to which the frequency controlling method according to the present invention is applied.

[0028]

In the surface acoustic wave device b, a quartz substrate 11 where an IDT electrode 12 is formed is electrically and mechanically connected to a ceramic package 14 through gold bumps 13 so that the IDT electrode 12 faces downward. This can be realized by a face down bonding (FDB) manufacturing method.

[0029]

Incidentally, the structure of the IDT electrode 12 formed on the quartz substrate 11 is the same as the structure of the IDT electrode 2 formed on the quartz substrate 1 of Fig. 1. Therefore, description thereof will be omitted.

In the surface acoustic wave device b having the above structure, the surface 11b that faces the electrode-formed surface of the quartz substrate 11 is etched, thereby controlling the thickness t of the quartz substrate 11 so that the desired center frequency is obtained as mentioned hereinafter. The ceramic package 14 is sealed after

controlling the frequency.

[0030]

With this structure, it is possible to easily miniaturize the surface acoustic wave device and it is not necessary to use an adhesive. Therefore, the inside of the package is stabilized. In addition, it is possible to etch the surface 11b that faces the surface of the quartz substrate 11 where the IDT electrode 12 is formed by performing plasma etching using a fluorine gas and thereby to control the thickness t of the quartz substrate 11 so that the desired center frequency is obtained.

[0031]

Fig. 3 is a cross-sectional view of the main portion of a surface acoustic wave device c, to which the frequency controlling method according to the present invention is applied.

In the surface acoustic wave device c, a quartz substrate 21 where an IDT electrode 22 is formed is connected to a ceramic package 26 using adhesives 24 so that the IDT electrode 22 faces upward. In addition, the electrode on the quartz substrate 21 is connected to the electrode of the ceramic package 26 through bonding wires 25.

[0032]

A reinforcing portion 28 is formed along the outer circumference on the back face of the quartz substrate 21, and a concave portion 23 is formed in the back face of the quartz substrate 21 by the reinforcing portion 28. The concave portion 23 is so formed as to at least correspond to the range where the IDT electrode 22 on the quartz

substrate 21 is formed. In the concave portion 23, the thickness t of the quartz substrate 21 is controlled by etching the quartz substrate so that the desired center frequency is obtained as described hereinafter.

[0033]

In order to control the frequency, an aperture 27 is formed on the bottom portion of the ceramic package 26 so as to correspond to the concave portion 23 of the quartz substrate 21. It is possible to control the thickness t of the quartz substrate 21 of the concave portion 23 by connecting the quartz substrate 21 to the ceramic package 26 and etching the back face of the quartz substrate 21 through the aperture 27. After controlling the frequency, the aperture 27 is closed and also the ceramic package 26 is sealed.

[0034]

Incidentally, the structure of the IDT electrode 22 formed on the quartz substrate 21 is the same as the IDT electrode 2 formed on the quartz substrate 1 of Fig. 1. Therefore, detailed description thereof will be omitted.

In the above structure, according to the surface acoustic wave device c, it is possible to perform wire bonding on the surface of the quartz substrate 21 where the IDT electrode 22 is formed and thereby to control the frequency so that the desired frequency is obtained.

[0035]

Next, embodiments of the frequency controlling method according to the present invention will be described.

A principle of the frequency controlling method according to the

present invention will be described with reference to Figs. 4 and 5 before describing the embodiments of the frequency controlling method.

Fig. 4 illustrates an example of results of measuring the amount of changes in the frequency with respect to the etching amount of the surface (the back face) that faces the electrode-formed surface (the front face) of the quartz substrate.

[0036]

The measurement results are obtained when the thickness $t/\lambda$ of the substrate obtained by standardizing the thickness t of the quartz substrate by an IDT wavelength $\lambda$ is '8' and '20'. In addition, the Euler angle is (0°, 143.5°, 0°), and the standardized electrode thickness $h/\lambda$ is 0.03. Herein, the thickness $h/\lambda$ of the standardized electrode is obtained by standardizing the thickness h of the IDT electrode 2 by the IDT wavelength $\lambda$.

[0037]

Fig. 5 illustrates an example of results of measuring the amount of changes in the frequency with respect to the etching amounts of the front face and the back face of the quartz substrate. The measurement results are obtained when the standardized substrate thickness $t/\lambda$ is '20', the Euler angle is (0°, 143.5°, 0°), and the standardized electrode thickness $h/\lambda$ is 0.03.

It is noted from Fig. 4 that it is possible to increase the center frequency (a resonance frequency) by etching the surface (the back face) that faces the electrode-formed surface of the quartz substrate to reduce the thickness of the quartz substrate, thereby controlling the

frequency of the surface acoustic wave device.

[0038]

In addition, it is noted from Fig. 5, compared with the case where the front face of the quartz substrate is etched, when the back face thereof is etched, that the amount of changes of the frequency with respect to the amount of etching are small, that it is suitable for precisely controlling the frequency, and that, in particular, it is suitable for controlling the frequency of a surface acoustic wave device with a high frequency and a short IDT wavelength.

Thus, according to the frequency controlling method of the present invention, it is possible to precisely control the frequency by etching the surface that faces the electrode-formed surface of the quartz substrate in consideration of the above points.

[0039]

Next, a case where a first embodiment of the method for controlling the frequency of the surface acoustic wave device according to the present invention is applied to the surface acoustic wave device a illustrated in Fig. 1 will be described with reference to Fig. 6.

In this case, for example, the thickness h of the IDT electrode 2 formed on the quartz substrate 1 is set to be slightly larger than the desired thickness so that the center frequency is slightly lower than the desired value (step S1).

[0040]

Next, a voltage is applied to the IDT electrode 2 and the center frequency is measured (the input and output are measured) (step S2). At

this time, the measured center frequency is slightly lower than the desired value. The back face 1b of the quartz substrate 1 is etched while checking the measured center frequency (step S3). Herein, the back face 1b of the quartz substrate 1 is preferably etched by dry etching.

[0041]

As a result, the measured center frequency gradually increases and approaches the desired value by etching the back face of the quartz substrate. Further, the etching is continuously performed until the center frequency reaches the desired value (steps S3 and S4). The etching is stopped at the point of time where the center frequency reaches the desired value (step S5).

According to the above-mentioned frequency controlling method, it is possible to precisely control the center frequency to be the desired value.

[0042]

Further, it is possible to control the frequency without eroding the electrode patterns formed on the electrode-formed surface of the quartz substrate. Therefore, it is possible to realize a surface acoustic wave device capable of reducing changes in the center frequency and of performing a stable operation for a long time.

Next, a case where a second embodiment of the method for controlling the frequency of the surface acoustic wave device according to the present invention is applied to the surface acoustic wave device a illustrated in Fig. 1 will be described with reference to Fig. 7.

[0043]

This is useful when the thickness h of the IDT electrodes 2 formed on the quartz substrates 1 of the surface acoustic wave devices a are not uniform in manufactured products and it is necessary to control the frequency.

First, a voltage is applied to the IDT electrode 2 to start measurement of the center frequency (step S11). Next, it is determined whether the measured center frequency is no more than or no less than the desired value (step S12).

[0044]

As a result, when it is determined that the measured center frequency is no more than the desired value, the process proceeds to the step S13. When the measured center frequency is no less than the desired value, the process proceeds to the step S19. When the measured center frequency agrees with the desired value, because it is not necessary to control the frequency, the controlling is terminated.

In the step S13, the surface of the IDT electrode 2 is etched, for example, wet-etched while checking the measured frequency. As a result, the measured center frequency increases in a short time by etching the surface of the IDT electrode. The etching is continuously performed until the measured center frequency reaches 'a temporary desired value' that is set to be slightly lower than the desired value of the center frequency (steps S13 and S14). The etching is stopped at the point of time where the measured center frequency reaches 'the temporary desired value' (step S15). In the steps S13 and S14, the frequency is roughly

controlled.

[0045]

Next, the back face 1b of the quartz substrate 1 is etched while checking the measured frequency (step S16). As a result, the measured center frequency gradually increases and approaches the desired value by etching the back face of the quartz substrate. The etching is continuously performed until the center frequency reaches the desired value (steps S16 and S17). The etching is stopped at the point of time where the center frequency reaches the desired value (step S18). In the steps S16 and S17, the frequency is finely controlled.

[0046]

On the other hand, in the step S19, the front face of the quartz substrate 1 is etched (for example, wet etched) while checking the measured frequency. As a result, the measured center frequency decreases in a short time by etching the front face of the quartz substrate. The etching is continuously performed until the measured center frequency reaches 'the temporary desired value' that is set to be slightly lower than the desired value of the center frequency (steps S19 and S20). The etching is stopped at the point of time where the measured center frequency reaches 'the temporary desired value' (step S21). In the steps S19 and S20, the frequency is roughly controlled.

[0047]

Next, the back face 1b of the quartz substrate 1 is etched while checking the measured frequency (step S22). As a result, the measured center frequency gradually rises and approaches the desired value by

etching the back face of the quartz substrate. The etching is continuously performed until the center frequency reaches the desired value (steps S22 and S23). The etching is stopped at the point of time where the measured center frequency reaches the desired value (step S24). In the steps S22 and S23, the frequency is finely controlled.

[0048]

According to the second embodiment of the frequency controlling method, even when the desired center frequencies are not uniform, it is possible to precisely control the frequency in a short time by roughly controlling the frequency in a short time by etching the front face of the quartz substrate or the surface of the IDT electrode and finely controlling the frequency by etching the back face of the quartz substrate.

[0049]

In addition, it is possible to roughly control the frequency by wet etching the surface of the IDT electrode or the front face of the quartz substrate and to finely control the frequency by plasma-etching the back face of the quartz substrate. Therefore, it is possible to prevent the frequency from changing after controlling the frequency due to the residing aluminum generated by etching the front face of the quartz substrate by plasma.

[0050]

Incidentally, according to the above embodiment, the frequency is roughly controlled by etching the front face of the quartz substrate (steps S19 and S20) or by etching the surface of the IDT electrode

(steps S13 and S14) and then, is finely controlled by etching the back face of the quartz substrate. However, the following controlling method can be used.

That is, when it is determined that after manufacturing the frequency in step S11, the center frequency is no more than 'a first desired frequency', the process immediately proceeds to the etching of the back face of the quartz substrate (step S16 or S22).

[0051]

In addition, if necessary, the center frequency may be controlled to be the desired value by sequentially etching the surface of the IDT electrode, the front face of the quartz substrate, and the back face of the quartz substrate.

Next, a case where a third embodiment of the method for controlling the frequency of the surface acoustic wave device according to the present invention is applied to the surface acoustic wave device b illustrated in Fig. 2 or the surface acoustic wave device c illustrated in Fig. 3 will be described.

[0052]

According to the third embodiment of the frequency controlling method, the etching device (the controlling device) illustrated in Fig. 8 is used. Therefore, a schematic structure of the etching device will be described.

As illustrated in Fig. 8, the etching device includes a chamber 41. An upper electrode 42a and a lower electrode 42b are arranged in the chamber 41. The upper electrode 42a is grounded, and the lower

electrode 42b is connected to a RF power supply (a high frequency power source) 44 through a capacitor 43. A supporting stand 45 is disposed on the lower electrode 42b. The surface acoustic wave device b is mounted on the supporting stand 45.

[0053]

In addition, measuring terminals 47 and 47 for measuring the frequency of the pseudo-longitudinal leaky surface acoustic wave device generated by the IDT electrode 12 of the surface acoustic wave device b are provided in the supporting stand 45. The measuring terminals 47 and 47 are connected to a frequency measuring system 49 through electric cables 48 and 48.

The frequency measuring system 49 supplies the measured center frequency to an RF power supply control portion 46. The RF power supply control portion 46 controls the operation of the RF power supply 44 in accordance with the supplied measured center frequency.

[0054]

Next, a case where the frequency of the surface acoustic wave device b is controlled using the etching device illustrated in Fig. 8 will be described.

In this case, for example, the thickness h of the IDT electrode 12 formed on the quartz substrate 11 is set to be slightly larger than the desired thickness so that the center frequency is slightly lower than the desired value.

[0055]

Next, the surface acoustic wave device b is mounted on the

supporting stand 45 so that the surface (the back face 11b) that faces the electrode-formed surface of the quartz substrate 11 faces upward. Therefore, the surface acoustic wave device b is disposed as illustrated in Fig. 8.

Then, the measurement of the center frequency of the surface acoustic wave device b is started by the frequency measuring system 49. At this time, the measured center frequency is slightly lower than the desired value. While exhausting the chamber 41, an etching gas is introduced into the chamber 41 and plasma is generated.

[0056]

At this time, a high frequency voltage is applied to between the upper electrode 42a and the lower electrode 42b by the RF power supply 44. Therefore, ions generated by the plasma are accelerated in an electric field, thereby etching the back face 11b of the quartz substrate 11. This allows the measured center frequency to gradually increase and approach the desired value by etching the back face of the quartz substrate.

During the etching, the frequency measuring system 49 measures the center frequency of the surface acoustic wave device b and supplies the measured value to the RF power supply control portion 46. The RF power supply control portion 46 compares the measured center frequency with the predetermined desired value and stops the operation of the RF power supply 44 when the measured center frequency reaches the desired value. This allows the above etching to be terminated.

[0057]

According to the frequency controlling method, even by the surface acoustic wave device, in which the quartz substrate where the IDT electrode is formed is mounted in the package, it is possible to precisely control the frequency by etching the surface that faces the electrode-formed surface of the quartz substrate.

Next, a case where the frequency of the surface acoustic wave device c illustrated in Fig. 3 is controlled using the etching device illustrated in Fig. 8 will be described.

[0058]

In this case, for example, the thickness h of the IDT electrode 22 formed on the quartz substrate 21 is set to be slightly larger than the desired thickness so that the center frequency is slightly lower than the desired value.

Next, the surface acoustic wave device c is mounted on the supporting stand 45 so that the surface that faces the electrode formed surface of the quartz substrate 21 faces upward. In this case, the thickness t of the quartz substrate 21 is controlled by etching the concave portion 23 of the quartz substrate 21 (see Fig. 3). The frequency controlling method is basically the same as that in the case of the above-mentioned surface acoustic wave device b. Therefore, description thereof will be omitted.

[0059]

According to the above-mentioned frequency controlling method, even by the surface acoustic wave device such that the surface acoustic wave element is mounted in the package so that the IDT electrode faces upward

and wire bonding is performed, it is possible to precisely control the frequency by etching the surface that faces the electrode-formed surface of the quartz substrate.

Next, an embodiment of the electronic apparatus according to the present invention will be described.

[0060]

Mobile telephones and keyless entry systems may be used as the electronic apparatus according to the present embodiment. In the case of the mobile telephone, the surface acoustic wave device illustrated in Figs. 1 to 3, which is controlled by the above-mentioned frequency controlling method, is used as the frequency-selecting filter of the mobile telephone. In the case of the keyless entry system, the surface acoustic wave device is used as the resonator of the oscillator of the keyless entry system.

[0061]

That is, the electronic apparatus according to the present embodiment includes the surface acoustic wave device as the filter and the resonator.

According to the electronic apparatus having the above structure, it is possible to provide various electronic apparatuses using the filters and the resonators capable of reducing changes in the center frequencies with the lapse of time and of performing stable operations for a long time.

[0062]

[Advantages]

As described above, according to the present invention, it is possible to realize a surface acoustic wave device capable of precisely controlling the frequency, of reducing changes in the center frequency with the lapse of time after controlling the frequency, and of performing a stable operation for a long time.

In addition, according to the present invention, it is possible to realize various electronic apparatuses using filters or vibrators, capable of reducing changes in the center frequencies with the lapse of time and of performing stable operations for a long time.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 illustrates a schematic structure of a surface acoustic wave device, to which a frequency controlling method according to the present invention is applied; Fig. 1(a) is a perspective view thereof; and Fig. (b) is a cross-sectional view taken along the line A-A of Fig. 1(a).

[Fig. 2] Fig. 2 is a cross-sectional view of a main portion of another surface acoustic wave device, to which the frequency controlling method according to the present invention is applied.

[Fig. 3] Fig. 3 is a cross-sectional view of a main portion of a further surface acoustic wave device, to which the frequency controlling method according to the present invention is applied.

[Fig. 4] Fig. 4 is a diagram illustrating an example of results of measuring the amount of changes in a frequency with respect to the etching amount of the back face of a quartz substrate.

[Fig. 5] Fig. 5 is a diagram illustrating an example of results of

measuring the amount of changes in the frequency with respect to the etching amounts of the front face and the back face of the quartz substrate.

[Fig. 6] Fig. 6 is a flowchart describing the order of the frequency controlling method according to a first embodiment of the present invention.

[Fig. 7] Fig. 7 is a flowchart describing the order of the frequency controlling method according to a second embodiment of the present invention.

[Fig. 8] Fig. 8 is a diagram illustrating a schematic structure of an etching device according to a third embodiment of the frequency controlling method of the present invention.

[Reference Numerals]

Reference numerals 1, 11 and 21 denote a quartz substrate; 2, 12 and 22 denote an IDT electrode; and 3a and 3b denote a reflector electrode.

[Name of Document] ABSTRACT

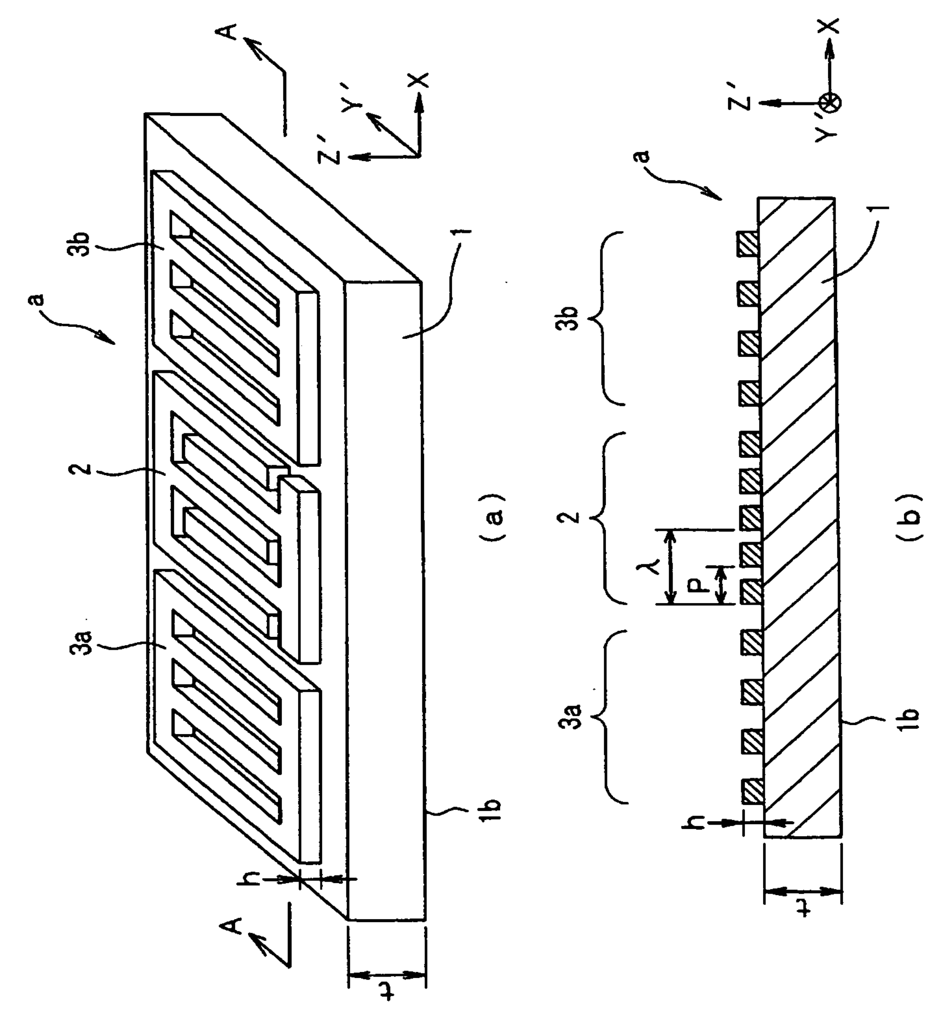
[Abstract]

[Object] To realize a surface acoustic wave device capable of precisely controlling a frequency, of reducing changes in the center frequency with the lapse of time after controlling the frequency, and of performing a stable operation for a long time.

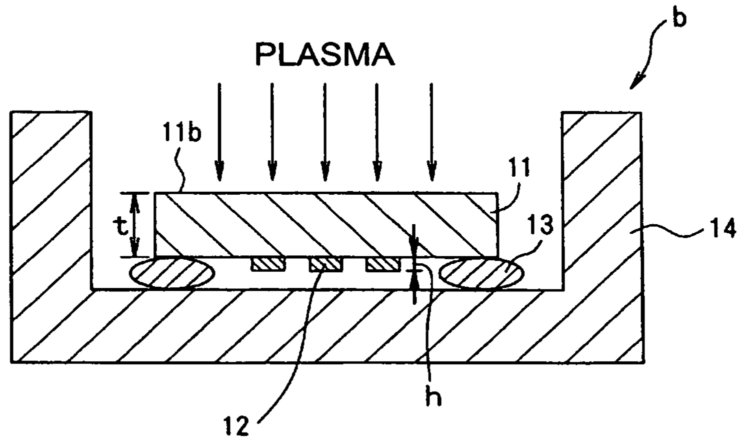
[Solving Means] The thickness h of an IDT electrode 2 formed on a quartz substrate 1 is set to be slightly larger than the desired thickness so that the center frequency is slightly lower than the desired value (S1). Next, a voltage is applied to the IDT electrode 2 to start measurement of the center frequency (S2). At this time, the measured center frequency is slightly lower than the desired value. The back face 1b of the quartz substrate 1 is etched while checking the measured center frequency (S3). As a result, the measured center frequency gradually increases and approaches the desired value by etching the bottom surface of the quartz substrate. Further, the etching is continuously performed until the center frequency reaches the desired value (S3 and S4). The etching is stopped at the point of time where the measured center frequency reaches the desired value (S5).

[Selected Figure] Fig. 6

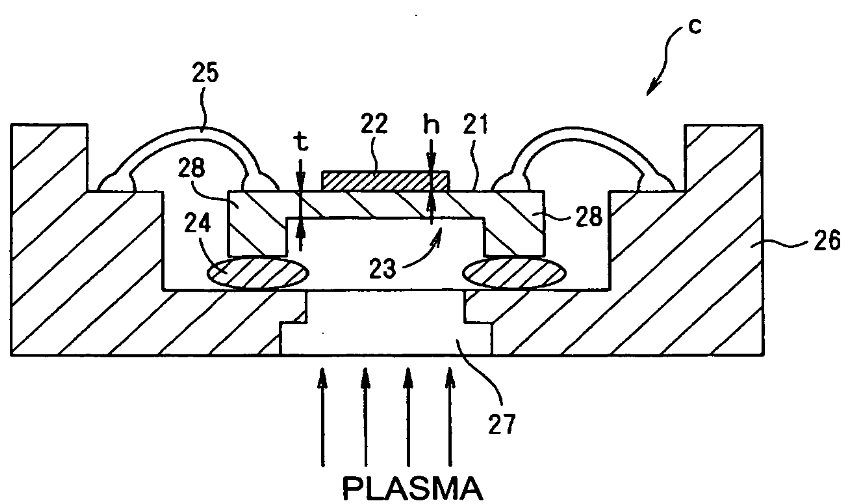
[Name of Document] DRAWINGS
[FIG. 1]



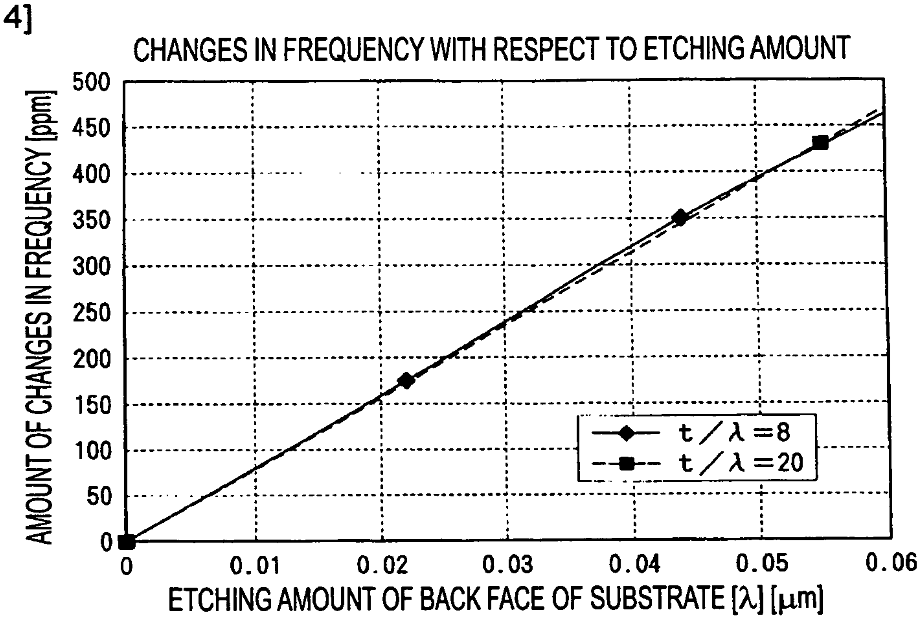
[FIG. 2]




[FIG. 3]

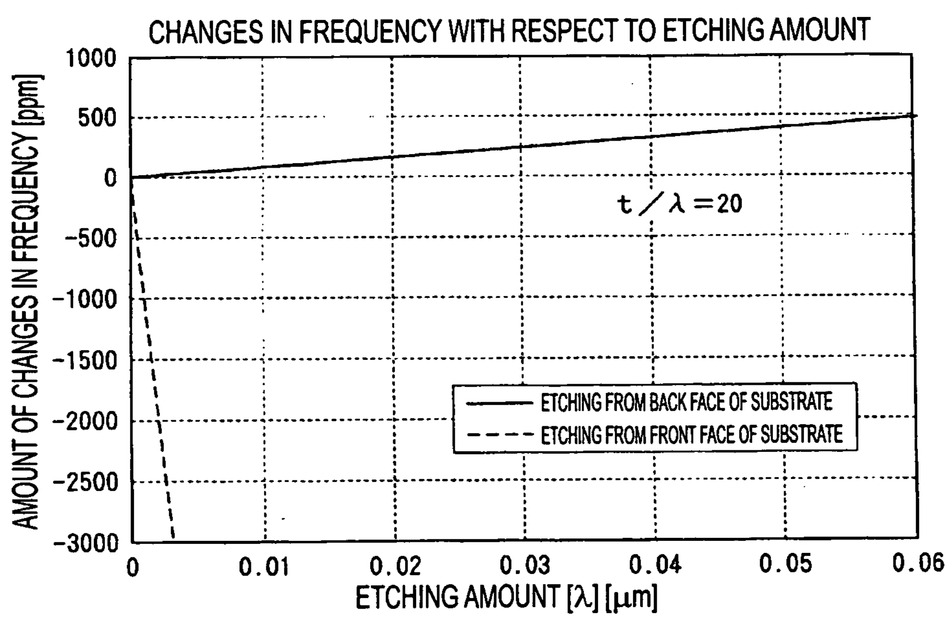


[FIG. 4]



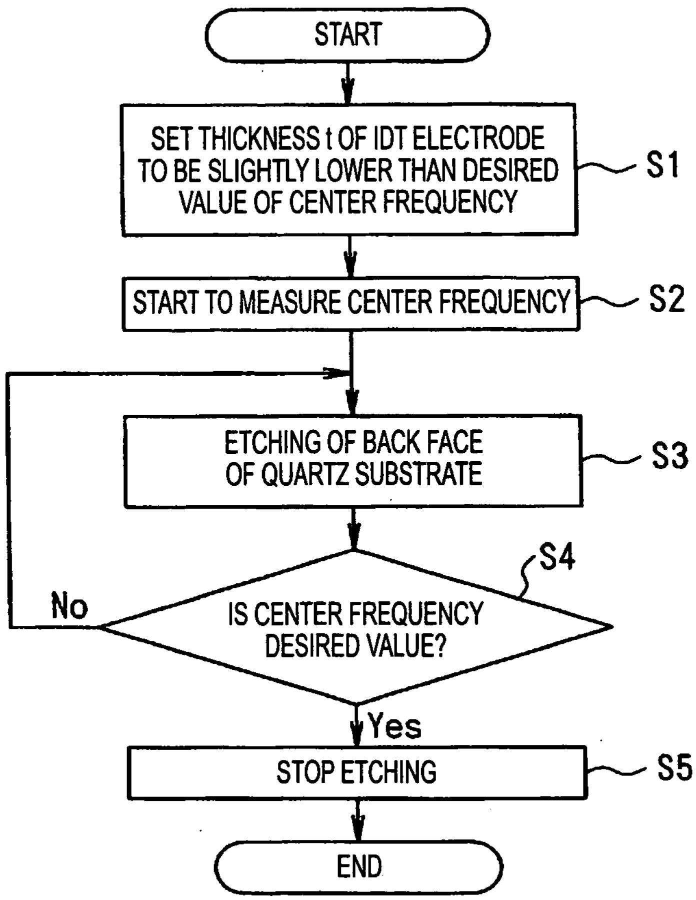
CHANGES IN FREQUENCY WITH RESPECT TO ETCHING AMOUNT
AMOUNT OF CHANGES IN FREQUENCY [ppm]
500
450
400
350
300
250
200
150
100
50
0
0
0.01
0.02
0.03
0.04
0.05
0.06
t／λ＝8
t／λ＝20
ETCHING AMOUNT OF BACK FACE OF SUBSTRATE [λ] [μm]


[FIG. 5]

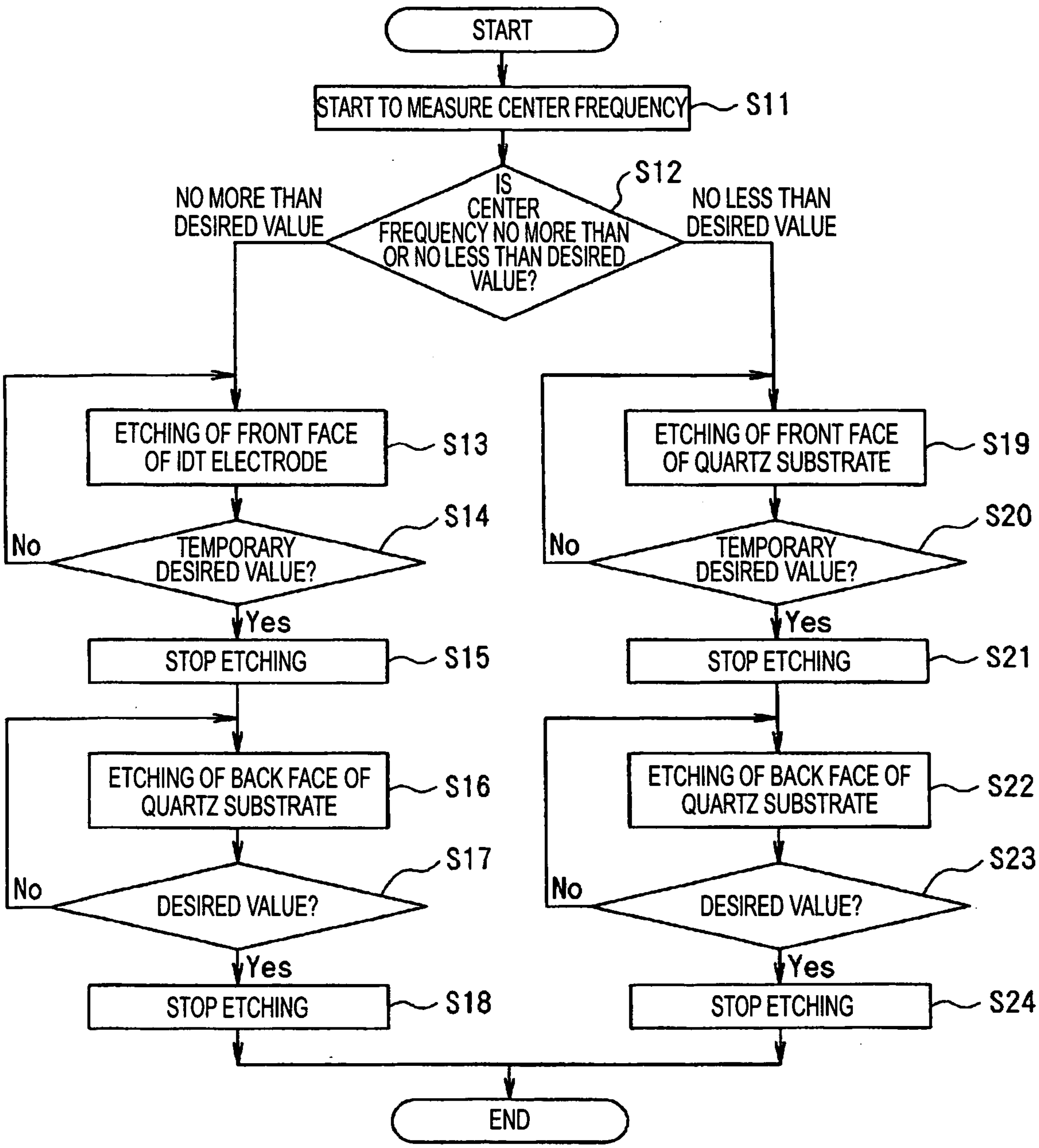


CHANGES IN FREQUENCY WITH RESPECT TO ETCHING AMOUNT
AMOUNT OF CHANGES IN FREQUENCY [ppm]
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
0
0.01
0.02
0.03
0.04
0.05
0.06
t／λ＝20
ETCHING FROM BACK FACE OF SUBSTRATE
ETCHING FROM FRONT FACE OF SUBSTRATE
ETCHING AMOUNT [λ] [μm]

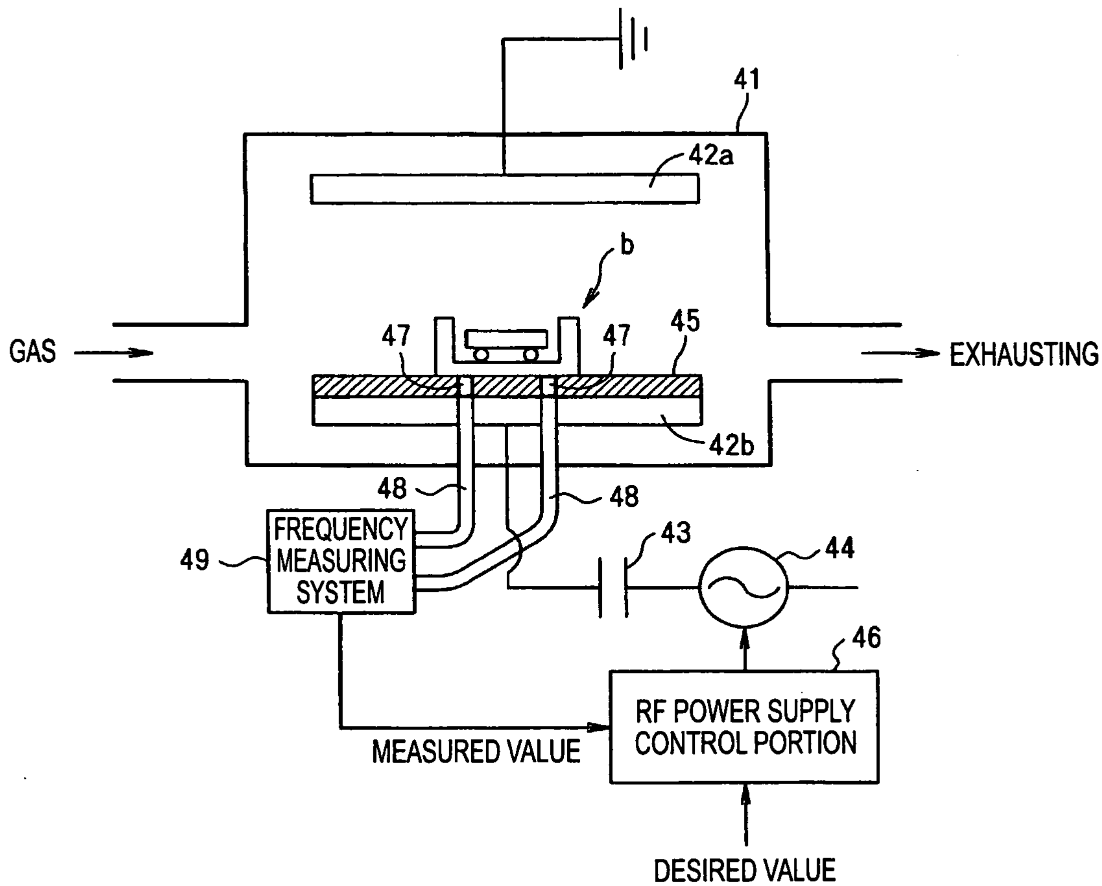
[FIG. 6]


START
SET THICKNESS t OF IDT ELECTRODE TO BE SLIGHTLY LOWER THAN DESIRED VALUE OF CENTER FREQUENCY
S1
START TO MEASURE CENTER FREQUENCY
S2
ETCHING OF BACK FACE OF QUARTZ SUBSTRATE
S3
S4
IS CENTER FREQUENCY DESIRED VALUE?
No
Yes
STOP ETCHING
S5
END

[FIG. 7]


START
START TO MEASURE CENTER FREQUENCY
S11
IS CENTER FREQUENCY NO MORE THAN OR NO LESS THAN DESIRED VALUE?
S12
NO MORE THAN DESIRED VALUE
NO LESS THAN DESIRED VALUE
ETCHING OF FRONT FACE OF IDT ELECTRODE
S13
TEMPORARY DESIRED VALUE?
S14
No
Yes
STOP ETCHING
S15
ETCHING OF BACK FACE OF QUARTZ SUBSTRATE
S16
DESIRED VALUE?
S17
No
Yes
STOP ETCHING
S18
ETCHING OF FRONT FACE OF QUARTZ SUBSTRATE
S19
TEMPORARY DESIRED VALUE?
S20
No
Yes
STOP ETCHING
S21
ETCHING OF BACK FACE OF QUARTZ SUBSTRATE
S22
DESIRED VALUE?
S23
No
Yes
STOP ETCHING
S24
END

[FIG. 8]


41
42a
b
GAS
47
47
45
EXHAUSTING
42b
48
48
FREQUENCY
MEASURING
SYSTEM
49
43
44
46
RF POWER SUPPLY
CONTROL PORTION
MEASURED VALUE
DESIRED VALUE